# P14.3 ANTICIPATING URBAN FLASH FLOODING USING BASIN UPSTREAM RAINFALL (BUR) AND GOOGLE EARTH

Thomas A. Green, Jr.*, R. S. Davis, and C. S. Strager
NOAA/NWSFO Pittsburgh, PA

## 1. INTRODUCTION

Flash flooding is a phenomenon that typically occurs over a short period of time, and influences a relatively small geographic area. While an individual basin may not receive enough rainfall to produce flooding, the contribution of increased streamflow from upstream basins may be a major contribution for flash flooding that might not otherwise occur. As a result, forecasters must account for the routing of water over more than just an individual basin. The integration of Basin Upstream Rainfall (BUR) into operational use would provide forecasters with a new radar rainfall tool for flash flood detection.

In addition, the effects of flash floods can be exacerbated when the streamflow of water is restricted or unexpectedly augmented by runoff from another basin. Streamflow can be restricted by urban drainage systems and the damming of debris at bridges or culverts. A second possibility for streamflow alteration may occur when flow from two basins intersects into a single channel. In urban areas, these 'flashpoints' may be the most dangerous locations for the public in a flooding situation.

When the remnants of Hurricane Ivan struck Pittsburgh, PA in September of 2004, several flashpoints significantly impacted the public. Some, but not all, of these flashpoints were anticipated as possible problem locations before flooding actually began. In post-event analysis, it was found that many locations where a major tributary entered the mainstream experienced some sort of flooding. BUR would provide a quantitative measure of the impacts of the merging stream channels. This paper outlines a procedure for proactively determining potential flashpoints before a flash flooding event occurs, provides a method for displaying flashpoints in Google Earth Pro (GEP), and demonstrates how this knowledge can be passed onto the public to meet the National Weather Service (NWS) mission of "protecting life and property."

## 2. STREAM CHANNEL FLASHPOINTS

Many NWS offices have begun incorporating GEP into operations, as it allows high-resolution imagery to be combined with varied types of information, including most GIS data. In many locations in the United States, high-resolution satellite imagery is available at a resolution between 0.25 and 1 km. Stream channel GIS datasets can be viewed in conjunction with GEP satellite imagery to see where stream channels are above or below ground, view bridges that pass over streams, and examine the density of buildings near a stream. Figure 1 shows the town of Millvale, PA with streams and terrain data displayed.

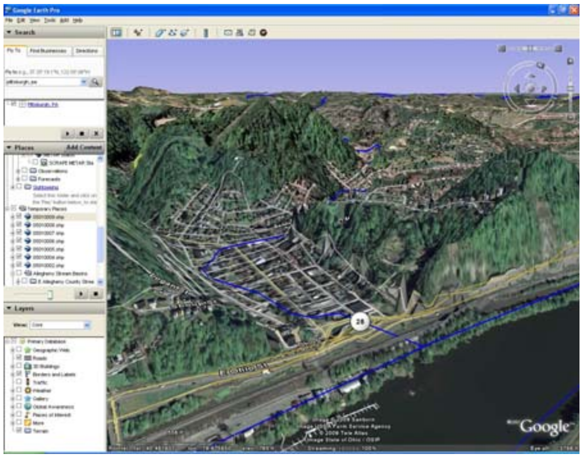

Fig. 1. Google Earth Pro imagery overlaid with GIS stream data and 3-dimensional terrain.

Version 5 of GEP also allows for full-screen viewing of "Street View" (previously only available on the Google Maps website), which shows images from street level taken by a vehicle on the ground (Fig. 2). However, Street View images cannot be combined with imported GIS data and are not available in all locations. Whether using satellite or Street View images, GEP can allow forecasters who are unfamiliar

---

* *Corresponding author address:* Thomas A. Green, Jr., 192 Shafer Dr., Moon Township, PA 15108; e-mail: tom.green@noaa.gov

with a particular location to "see" an area of concern, allowing for additional situational awareness when determining the potential of flash flooding.

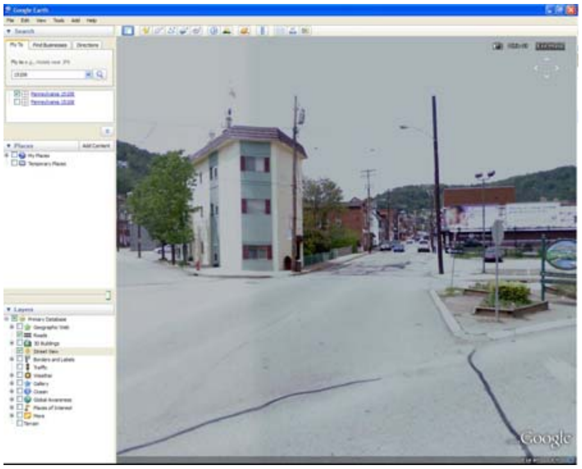

Fig. 2. Full-screen "Street View" imagery.

For locations where historical records of floods exist, markers could be placed in GEP highlighting which areas were affected, showing forecasters which locations were prone to flash flooding. Regarding the potential for future events, offices could place markers at the intersection of stream channels, where the higher potential for flash flooding exists. It was noted earlier that GIS stream channel datasets could be viewed with GEP imagery. Highly urbanized locations where two stream channels come together could also be marked in GEP as potential, but unverified, locations where flash flooding might occur.

## 3. FFMP AND BASIN WATERSHEDS

A primary program used by the NWS for hydrology operations is FFMP (Flash Flood Monitoring and Prediction). FFMP is an integrated suite of multi-sensor (primarily radar) applications which detects, analyzes, and monitors precipitation and generates short-term warning guidance for flash flooding automatically. NWS forecast offices receive 1-, 3-, and 6-hour (some also receive 12-hour and 24-hour) flash flood guidance (FFG) from River Forecast Centers three times a day. FFMP then compares radar data from individual bins in a given watershed to the FFG to alert forecasters to locations where rainfall accumulation is nearing or exceeding FFG. At the Pittsburgh office, watersheds are examined in both a broader "stream basin" view (~10 to 1000 km$^2$) and a smaller "FFMP basin" view (~1 to 10 km$^2$), with stream basins composed of multiple FFMP basins (Fig. 3, 4).

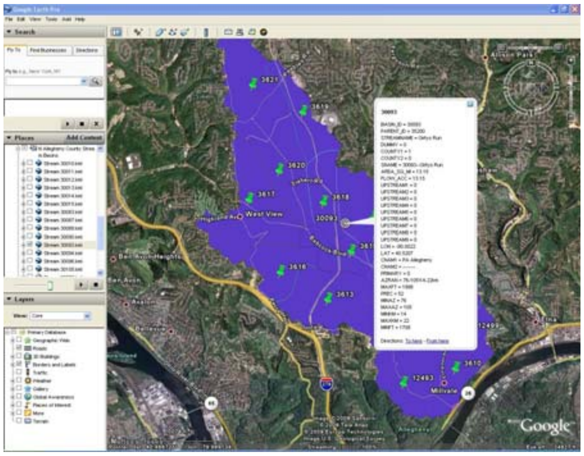

Fig. 3. Stream basin, with additional information available by clicking on placemark in the center of the basin.

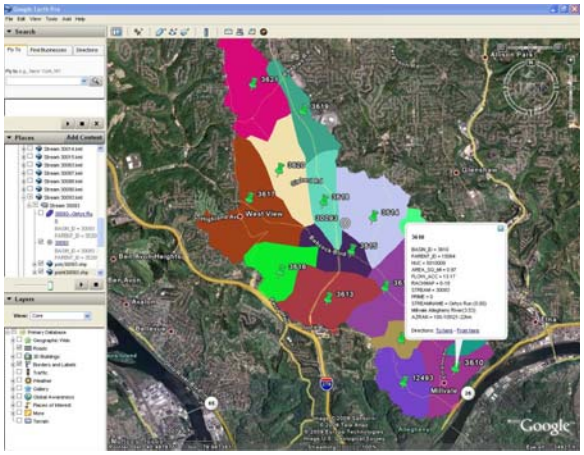

Fig. 4. Individual FFMP basins in the stream basin from Figure 3, with additional information available.

FFMP assumes that flooding will not occur in a basin unless the average basin rainfall (ABR) exceeds FFG. FFMP does not account for rainfall that occurs in one basin and flows downstream into a second basin.

FFMP data cannot be imported into GEP, because of the varying calculations that need to be done with the FFG and rainfall rates as determined by the radar and other sensors.

However, multiple radar products can be imported into GEP. Those radar products that can be viewed in GEP and are relevant to flash flood monitoring include base and composite reflectivity, 1 hour precipitation, and storm total precipitation (Fig. 5). The superior map backgrounds available in GEP overlaid with radar data can be an important supplement to the data viewed in FFMP.

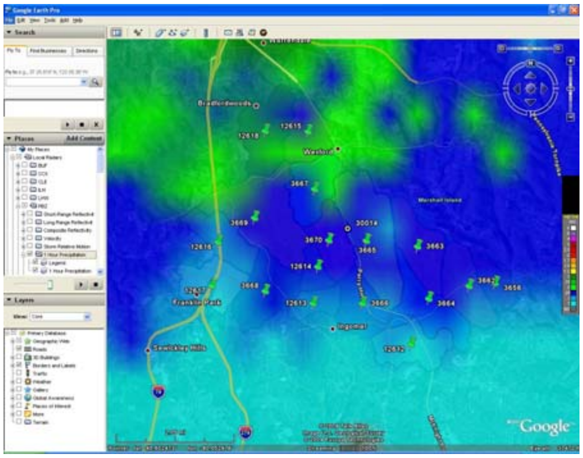

Fig. 5. 1-hour precipitation overlaid on FFMP basins.

## 4. BASIN UPSTREAM RAINFALL

The basin upstream rainfall (BUR) is the ABR for the entire upstream contributing area of a single FFMP basin segment. Although ABR can be used to determine the flash flood threat on small tributaries within a FFMP basin, BUR is necessary to determine the flash flood threat on the main stem stream channel. The larger a given watershed, the greater the importance of BUR in a non-headwaters basin (by definition, BUR is equal to ABR in a headwaters basin). The upstream area, defined as flow accumulation in the National Severe Storms Laboratory (NSSL) FFMP stream database, can be displayed in GEP, showing areas with the largest flow accumulation and greatest potential for flash floods on the main stem stream channel. FFMP would still be necessary to calculate BUR, due to the combination of average basin rainfall and flow accumulation parameters.

Superior zooming capability of GEP allows for forecasters to zoom to street level to determine which roads are near the main stream channel. Specific roads that are in the vicinity of a flooding stream channel could be included in the text of a flash flood statement or warning, passing along potentially life-saving information to the public (Fig. 6).

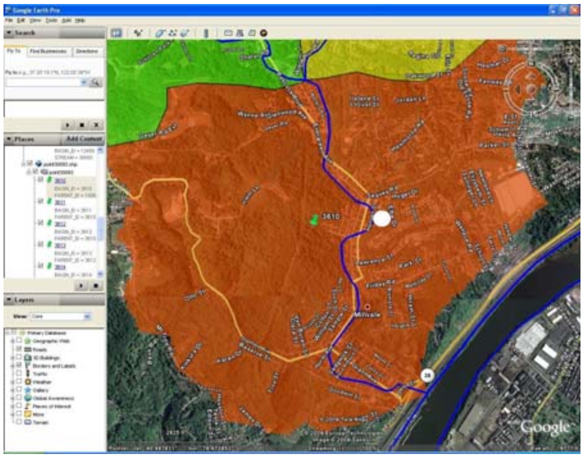

Fig. 6. FFMP basins overlaid with streams. Public products could highlight Evergreen Ave and Grant Ave.

## 5. CASE STUDIES

Girtys Run is a stream where major flash flooding occurs in the Pittsburgh metropolitan area. The stream basin is highly urbanized (Fig. 7).

Fig. 7. Photograph looking northward along the main stem stream of Girty's Run at white circled location in Fig. 6.

Girtys Run flows through the town of Millvale before emptying into the Allegheny River. The stream basin measures 34.2 km$^2$

(13.2 mi$^2$), and was composed of 12 FFMP basins in 2007. Seven of the 12 FFMP basins are headwaters basins, with Girtys Run passing through five non-headwaters basins (Fig. 8, 9).

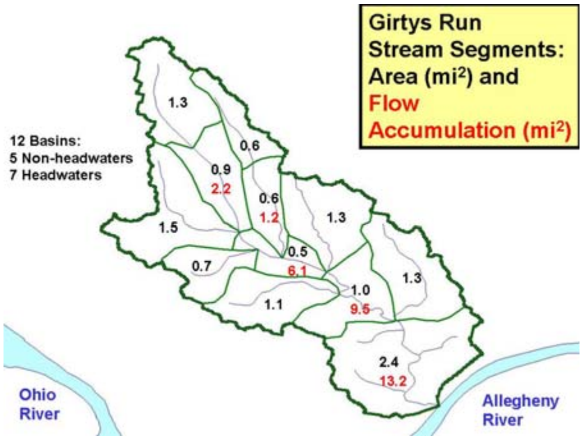

Fig. 8. Stream basin with square mileage (in black) and flow accumulation (in red) for each FFMP basin.

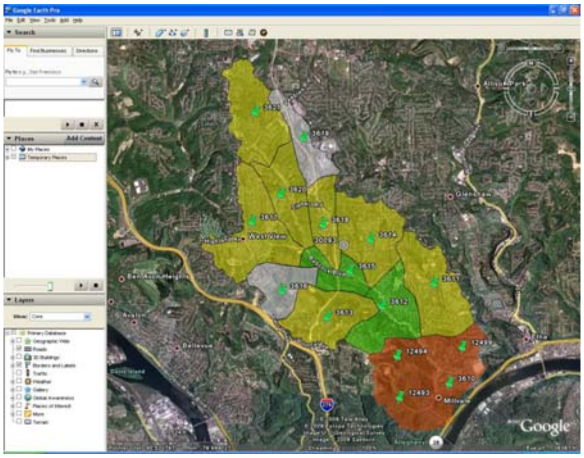

Fig. 9. FFMP basins color-coded by flow accumulation.

Experience with past flash flood events in the basin has shown that 2.5 cm (~1 in) of rain in an hour brings the creek to near bank full and 5 cm (~2 inches) in one hour produces significant flooding of homes. On the morning of August 9, 2007, widespread rainfall between 4 to 8 cm (~1.5 to ~3 in) occurred across the basin in just over 1 hour. When examining ABR, Millvale actually received the least rainfall of all the FFMP basins in the Girtys Run watershed (Fig. 10). The ABR value in the Millvale FFMP basin was 4.3 cm (1.7 in), which would be enough to cause minor flooding. When BUR is considered, the value in the Millvale basin increases to 6.2 cm (2.4 in), implying more serious flooding, which did occur (Fig. 11).

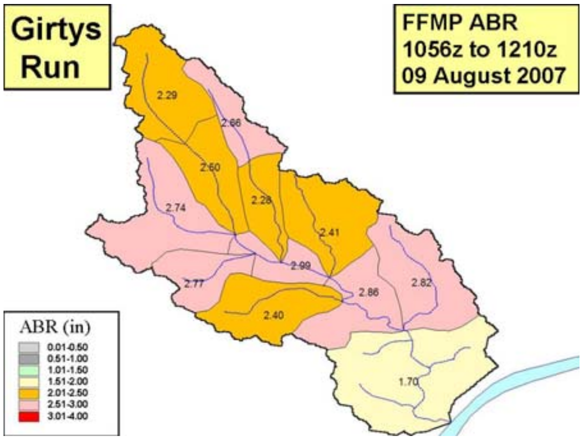

Fig. 10. ABR from 1056Z to 1210Z on August 9, 2007.

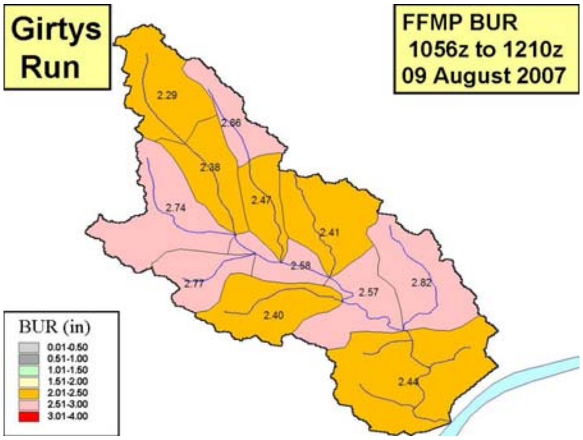

Fig. 11. Same as Fig. 9, except BUR (note 0.74 inch increase in the southeast, where worst flooding occurred in Millvale).

Serious flash flooding also occurred in Shadyside, Ohio on June 14, 1990. Heavy rain fell in the headwaters and much less rain fell in the downstream segment where people were swept away. 26 people were killed in this flash flood event. Figures 12 and 13 show the comparison between ABR and BUR, with a substantial increase in BUR in Shadyside, where a majority of the deaths occurred.

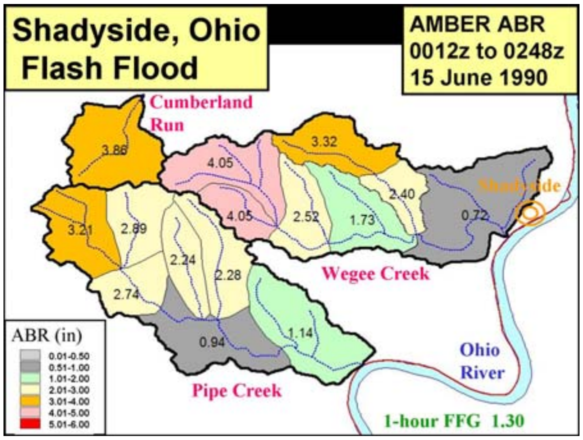

Fig. 12. ABR from 0012Z to 0248Z on June 15, 1990.

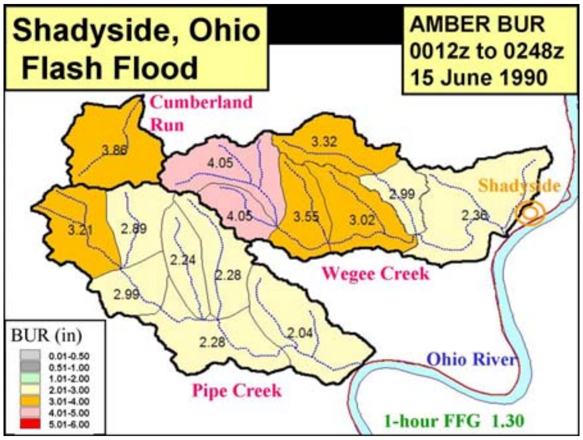

Fig. 13. Same as Fig. 12, except BUR (note 1.64 inch increase in Shadyside, where worst flooding occurred and most fatalities occurred).

## 6. CONCLUSIONS

The development of GEP allows for forecasters to view locations in their forecast area which they may be unfamiliar with and allow for greater situational awareness of the terrain. In addition, radar products that can be imported into GEP may allow for better comprehension when viewed in GEP as opposed to other programs. Locations that are flash-flood prone can be highlighted so that additional attention is given to those locations.

BUR is a concept that allows for greater monitoring of flash flooding due to rainfall in non-headwaters basins. While BUR is not something currently viewable in GEP, the flow accumulation that is included in BUR could be visualized in GEP, allowing forecasters to distinguish areas of low and high flow accumulation and increased flash flood threat from upstream rainfall.